

UNITED STATES PATENT APPLICATION

**HEARING INSTRUMENT WITH DATA TRANSMISSION
INTERFERENCE BLOCKING**

INVENTOR

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HEARING INSTRUMENT WITH DATA TRANSMISSION INTERFERENCE BLOCKING

Technical Field

5 This application relates generally to hearing instruments with data communication capabilities and, more particularly, to methods, devices and systems to block interference associated with data transmission from an input of a hearing aid receiver.

Background

10 Hearing aids include a microphone. The microphone converts acoustic signals into an electrical signal, referred to herein as an acoustic-based signal. The electrical signal is processed, and the resulting processed signals also can be referred to as an acoustic-based signal or a signal representative of an acoustic-
15 based signal. Hearing aids also include a receiver which functions as a speaker. The acoustic-based signal is processed and presented to the receiver, which transforms the acoustic-based signal into an audible sound wave, herein referred to as an output acoustic signal. The microphone and receiver form part of an acoustic signal processing section of the hearing aid.

20 Hearing aids also include communication or data transmission components used to communicate with devices that are external to the hearing aid. One example of data transmission components includes wireless transceivers, such as those used to wirelessly communicate with hearing aid programmers. Programmers are used to program various functions of the hearing aid. The transceivers are also able to
25 wirelessly communicate with other hearing aids, or with assisted listening devices. The transceiver forms part of a data signal processing section of the hearing aid.

 Data transmission signals generate radio frequency (RF) waves, which can interfere with the acoustic signal processing section of the hearing aids. The microphone is particularly vulnerable to interference from the data transmission
30 signals. The interference picked up by the microphone is propagated within the

acoustic-based signal, and is transformed into an unpleasant output acoustic signal by the receiver.

There is a need in the art to provide an improved hearing instrument that does not transform data transmission interference into unpleasant output acoustic
5 signals.

Summary

The above-mentioned problems are addressed by the present subject matter and will be understood by reading and studying the following specification.

10 Various aspects and embodiments of the present subject matter block interference associated with the data transmission from reaching the receiver. Various embodiments provide silence to a user of the hearing aid for a brief time period associated with the duration of the data transmission. Various embodiments provide a substitute sound to a user of the hearing aid by providing a substitute waveform to
15 the receiver. In various embodiments, the substitute waveform is calculated or processed according to the sounds received by the microphone immediately preceding the proposed interference such that the waveform has the same frequency (pitch) and amplitude (volume). Additionally, in various embodiments, the ends of the substitute waveform are appropriately adjusted or annealed to connect the ends
20 with the preceding and succeeding waveforms such that the hearer does not experience an audible break in the output acoustic signal during the data transmissions and the transitions leading in to and out from the data transmissions.

One aspect of the present subject matter relates to a method to block data transmission interference from an input of a receiver in a hearing instrument.

25 According to various embodiments of the method, an acoustic-based signal representative of sound received at a microphone system is received. It is determined if a trigger associated with a data transmission has occurred. A signal representative of the acoustic-based signal is presented to the input of the receiver when the trigger has not occurred such that the receiver converts the acoustic-based
30 signal into an output acoustic signal. The signal representative of the acoustic-based signal is blocked from the input of the receiver when the trigger has occurred such

that data transmission interference is blocked from being converted into the acoustic signal. In various embodiments, the method further comprises presenting a signal representative of a substitute waveform to the input of the receiver when the trigger has occurred.

5 One aspect of the present subject matter relates to a hearing instrument. Various embodiments of the hearing instrument include a data receiver to receive a data transmission, a microphone system to generate an acoustic-based signal, and a hearing instrument receiver to receive and convert a signal representative of the acoustic-based signal into an output acoustic signal. The hearing instrument further
10 includes means to block the acoustic-based signal for at least a portion of a time period when the data receiver receives a data transmission such that the output acoustic signal does not include noise attributed to the data transmission.

 Various embodiments of the hearing instrument include a data receiver to receive a data transmission, a microphone system to generate an acoustic-based
15 signal, and a switch. Various embodiments implement the switch using software, hardware or a combination of software and hardware. The switch has a first input and an output, and is configured to selectively connect the first input to the output. The hearing instrument includes a first signal path to carry a signal representative of the acoustic-based signal from the microphone system to the first input of the
20 switch. The hearing instrument further includes a receiver to convert an output signal from the output of the switch into an output acoustic signal. The hearing instrument further includes a controller to receive a trigger signal indicative of a data transmission occurrence, and to communicate with the switch to selectively disconnect the first input from the output during at least a portion of the data
25 transmission occurrence such that interference associated with the data transmission occurrence is not transferred to the hearing instrument receiver.

 Various embodiments of the present subject matter store a predetermined amount of time (e.g. 1-50 ms) of audio in a circular buffer of the hearing aid using digital signal processing. As this audio data is sent to the receiver, the device
30 receives data from a wireless antenna input of the hearing aid, and programs that data into non-volatile memory. A copy of the waveform just preceding the intended

period of interference is formed, and presented to the receiver during the period of interference. Silence can be substituted instead of the waveform during the outage when the silence is not noticeable.

5 This Summary is an overview of some of the teachings of the present application and not intended to be an exclusive or exhaustive treatment of the present subject matter. Further details about the present subject matter are found in the detailed description and appended claims. Other aspects will be apparent to persons skilled in the art upon reading and understanding the following detailed description and viewing the drawings that form a part thereof, each of which are not
10 to be taken in a limiting sense. The scope of the present invention is defined by the appended claims and their equivalents.

Brief Description of the Drawings

FIG. 1 illustrates a high-level block diagram of portions of a hearing
15 instrument, according to various embodiments of the present subject matter.

FIG. 2 illustrates a method for blocking data transmission interference from a receiver input via substitution, according to various embodiments of the present subject matter.

FIG. 3 illustrates a method for blocking data transmission interference from
20 a receiver input via sampling and substitution, according to various embodiments of the present subject matter.

FIG. 4 illustrates a block diagram of a hearing instrument, according to various embodiments of the present subject matter.

FIG. 5 illustrates a block diagram of the waveform signal processing module
25 shown in FIG. 4, according to various embodiments of the present subject matter.

FIG. 6 illustrates a waveform signal processed by the waveform signal processing module shown in FIG. 5, according to various embodiments of the present subject matter.

Detailed Description

The following detailed description of the present subject matter refers to the accompanying drawings which show, by way of illustration, specific aspects and embodiments in which the present subject matter may be practiced. These
5 embodiments are described in sufficient detail to enable those skilled in the art to practice the present subject matter. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the present subject matter. References to “an”, “one”, or “various”
10 embodiments in this disclosure are not necessarily to the same embodiment, and such references contemplate more than one embodiment. This description references signal transmission lines using labels, and to simplify the discussion, also references the signals transmitted on the signal transmission lines using the same labels. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present subject matter is defined only by the appended
15 claims, along with the full scope of legal equivalents to which such claims are entitled.

FIG. 1 illustrates a high-level block diagram of portions of a hearing instrument, according to various embodiments of the present subject matter. The hearing instrument is illustrated as a hearing aid 100. Various portions of the
20 hearing aid, such as the microphone system and the receiver of the acoustic signal processing section and the transceiver of the data signal processing section, are not illustrated in FIG. 1 to simplify the illustration and the corresponding discussion. A hearing aid embodiment, including the microphone system and the receiver, is discussed below with respect to FIG. 4.

25 The hearing aid 100 includes a controller 101 and a blocking module 102. One of ordinary skill in the art will understand, upon reading and comprehending this disclosure, that the controller 101 is used to control a number of hearing aid operations. As illustrated in FIG. 1, the controller 101 is adapted to receive a data signal trigger 103, and to appropriately control the blocking module 102 via control
30 line 104 based on the data signal trigger 103.

The blocking module 102 receives an acoustic-based signal 105 from the microphone system. One of ordinary skill in the art will understand that the acoustic-based signal generated by the microphone system can be processed to reflect a processed signal representative of the acoustic based signal generated by the microphone system. Line 105 is intended to reflect the acoustic-based signal or any processed signal representative of the acoustic based signal. The blocking module 102 selectively passes the acoustic-based signal 105 through to the hearing aid receiver input 106. In response to a data signal trigger 103, the controller 101 controls the blocking module 102 to block the acoustic-based signal from passing through to the hearing aid receiver input 106. The blocking module 102 is illustrated as a switch to illustrate the blocking, or disconnect, function of the blocking module 102. One of ordinary skill in the art will understand, upon reading and comprehending this disclosure, that the switching function of the blocking module 102 can be implemented using software, using hardware, or using a combination of software and hardware. By blocking the acoustic-based signal from the input of the receiver in response to the trigger 103, the present subject matter blocks data transmission interference (e.g. RF signals picked up by the microphone and hybrid wiring) from being converted into the output acoustic signal.

In various embodiments, no significant signal is presented to the hearing aid receiver input 106 in response to the data signal trigger 103 such that, during a data transmission, the hearing aid receiver does not transmit an acoustic signal. In these embodiments, the hearing aid user is presented with silence during the data transmission. In these embodiments, the blocking module 102 can be illustrated as a disconnect switch that selectively disconnects the receiver input 106 from the acoustic-based signal 105.

In various embodiments, as illustrated in FIG. 1, the hearing aid provides a substitute waveform 107 that is passed to the hearing aid input 106 such that, during a data transmission, the hearing aid receiver transmits an acoustic signal corresponding to the substitute waveform. In various embodiments, the substitute waveform presented to the receiver results in a predetermined ambient sound. In various embodiments, the substitute waveform presented to the receiver results in a

short duplication of a sound heard by the hearing aid user prior to the data transmission. The length of the substitute waveform is within a range of 1 - 50 ms in various embodiments. In various embodiments, the substitute waveform is calculated such that the listening experience of the hearing aid user is not noticeably interrupted.

FIG. 2 illustrates a method for blocking data transmission interference from a receiver input via substitution, according to various embodiments of the present subject matter. The illustration includes two inputs. A first input, represented at 208, represents an acoustic based signal representative of sound received at a microphone system of the hearing aid. A second input, represented at 209, represents a wireless transmission event. At 210, a determination is made as to whether there is a transmission event. If a transmission event (or trigger for a transmission event) has not occurred, the acoustic-based signal is presented to an input of a hearing aid receiver, as represented at 211. In the illustrated embodiment, the method proceeds back to 210 to again determine whether there is a transmission event. The acoustic-based signal can pick up transmission noise if, at 210, a transmission event (or trigger for a transmission event) has occurred, the acoustic-based signal can pick up transmission noise. Thus, at 212, the wireless transmission noise is substituted with a desired waveform at 212, and the desired waveform is presented to a receiver input at 213. In the illustrated embodiment, the method proceeds back to 210 to again determine whether there is a transmission event. One of ordinary skill in the art will understand, upon reading and comprehending this disclosure, that in embodiments of the present subject matter in which the acoustic-based signal is blocked and another waveform is not substituted for the acoustic-based signal, the illustrated method proceeds from 210 along dotted line 214 to skip the presentation of the acoustic-based signal to the receiver input 211.

FIG. 3 illustrates a method for blocking data transmission interference from a receiver input via sampling and substitution, according to various embodiments of the present subject matter. A first input, represented at 308, represents an acoustic based signal representative of sound received at a microphone system of the hearing aid. A second input, represented at 309, represents a wireless transmission event.

At 310, a determination is made as to whether there is a transmission event. If a transmission event (or trigger for a transmission event) has not occurred, the acoustic-based signal is presented to an input of a hearing aid receiver, as represented at 311. At 315, the acoustic-based signal is buffered, also referred to as
5 sampled and stored, to form a desired waveform for substitution when there is a transmission event. Various embodiments buffer 1-50 ms of the acoustic-based signal. In the illustrated embodiment, the method proceeds from 311 back to 310 to again determine whether there is a transmission event. If, at 310, a transmission event (or trigger for a transmission event) has occurred, the wireless transmission
10 noise is substituted with a desired waveform at 312, and the desired waveform is presented to a receiver input at 313. The substituted waveform was previously sampled and stored from the acoustic-based signal at a time preceding the transmission event. In the illustrated embodiment, the method proceeds back to 310 again determine whether there is a transmission event.

15 FIG. 4 illustrates a block diagram of a hearing instrument, according to various embodiments of the present subject matter. The hearing instrument is illustrated as a hearing aid 400, which generally corresponds to hearing aid 100 of FIG. 1. As was illustrated in FIG. 1, the hearing aid 400 illustrated in FIG. 4 includes a controller 401 and a blocking module 402. The blocking module is
20 labeled in the illustration as a substitution module. The controller 401 is adapted to control various portions of the hearing aid, as generally represented by the dotted lines extending away from the controller 401. The controller 401 is adapted to receive a data signal trigger 403 which is labeled as a substitution enable signal, and to appropriately control the substitution module 402 via control line 404 based on
25 the data signal trigger 403. The substitution module 402 receives an acoustic-based signal 405, and selectively passes the acoustic-based signal 405 through to line 406. In response to a data signal trigger 403, the controller 401 controls the substitution module 402 to block the acoustic-based signal from passing through to line 406. By blocking the acoustic-based signal from the input of the receiver in response to the
30 trigger 403, the present subject matter blocks data transmission interference from being converted into the output acoustic signal.

FIG. 4 further illustrates an external source of data 416, represented as a wireless transceiver. The data source 416 transmits a data signal to the hearing aid 400. In various embodiments, the hearing aid includes a wireless transceiver 417 adapted to wirelessly communicate with the external transceiver 416. The
5 illustrated transceiver 417 receives a wireless data communication 418, and presents a corresponding data signal 419 to the controller 401. It is understood that the functions of the transceiver can be performed by a transmitter and a receiver. The illustrated controller 401 includes a programming module 420 used to program the hearing aid 400. The programming module 420 is adapted to store programming
10 instructions in a program memory 421 via data path 422.

FIG. 4 also illustrates a trigger generator 423 to generate a substitution enable signal 403 corresponding to a data transmission event. In various embodiments, the trigger generator 423 includes a carrier sense module 424 used to sense a carrier wave of the data transmission and generate the substitution enable
15 signal 403 when the data transmission carrier signal is sensed. In various embodiments, the trigger generator 423 includes a timer used to anticipate a planned data transmission, and generate the substitution enable signal 403 in preparation for the planned data transmission. In various embodiments, the trigger generator 423 includes another signal input means, as may be appropriate for a particular hearing
20 aid design, used to signal a data transmission event or occurrence. One of ordinary skill in the art will understand, upon reading and comprehending this disclosure, that the data transmission occurs over a period of time, and that the substitution enable signal can be active for the entire period of time or a portion thereof.

FIG. 4 further illustrates an acoustic source 427, which generates sound.
25 The generated sound is referred to herein as an input acoustic waveform 428. The hearing aid 400 includes a microphone system 429 to receive the input acoustic waveform 428 and generate an analog acoustic-based signal 430. The microphone system 429 includes one or more microphones and associated circuitry to perform the desired function. An analog-to-digital (A/D) converter 431 converts the analog
30 acoustic-based signal 430 to a digital acoustic-based signal 432.

A digital signal processing (DSP) module 433 receives and processes the digital acoustic-based signal 432 for presentation to the hearing aid receiver. One of ordinary skill in the art will understand, upon reading and comprehending this disclosure, the functions of the DSP module. One such function includes filtering.

5 The output of the DSP module 433 presents an acoustic-based signal 405, or more particularly a signal representative of the acoustic-based signal 430 generated by the microphone system 429, to the substitution module. The substitution module 402, under the control of the controller 401, selectively passes the acoustic-based signal 405 to a digital-to-analog (D/A) converter 434, which converts the digital output
10 signal 406 to an analog output signal 435. The analog output signal 435 is presented to an input of the hearing aid receiver 436. The receiver 436 functions as a speaker, and produces an output acoustic signal 437 that is capable of being heard by the user of the hearing aid.

The hearing aid 400 includes a waveform memory 438. Data representative
15 of substitute waveforms are capable of being stored in the waveform memory 438. The illustrated substitute waveforms include a sampled waveform 439 and a predetermined ambient waveform 440. A waveform signal is transmitted from the memory waveform 438 via path 441 to a waveform signal processing module 442. An output of the waveform signal processing module 442 presents a processed
20 waveform signal on line 407 to the substitution module 402. The illustrated substitution module 402 is illustrated as a switch with three inputs: a processed waveform signal (e.g. sample or ambient waveforms) input; a silence input; and a processed acoustic-based signal input. The silence input is illustrated as a disconnected receiver 436, such as the situation when neither the processed
25 acoustic-based signal at 405 nor the processed waveform signal at 407 are passed to the receiver 436. Various embodiments include only some of the above-described options, various embodiments include all of these options, and various embodiments include different waveform substitution options.

Various embodiments of the hearing aid 400 includes a sample module 443,
30 which together with the waveform memory 438, is capable of functioning as a circular buffer. The signal at 406 is sampled by the sample module 443 and stored

at 439 in the waveform memory 438. In various embodiments, the length of the stored sample waveforms is within a range of approximately 1 to 50 ms.

In various embodiments, the waveform signal processing module 442 is configured to adjust morphology parameters of the substitute waveform based on
 5 the morphology of the acoustic-based signal that precedes and succeeds data transmission. Thus, the waveform signal processing module 442 matches the frequency (pitch) and amplitude (volume) of the preceding and succeeding signals. In various embodiments, the morphology of the acoustic-based signal is determined from the sampled signals taken by the sample module 443. In various
 10 embodiments, the morphology of the acoustic-based signal is determined using the DSP module 433, which communicates this morphology information to the waveform signal processing module 442 via line 444.

FIG. 5 illustrates a block diagram of the waveform signal processing module shown in FIG. 4, according to various embodiments of the present subject matter.
 15 The DSP module 533 receives an acoustic-based signal 532, and outputs a processed acoustic-based signal 505. The illustrated DSP module 533 also provides morphology information 544 for the acoustic-based signal for use by the waveform signal processing module 542. According to various embodiments, the morphology 544 includes phase information 545, frequency information 546 and amplitude
 20 information 547 associated with the acoustic-based signal. The waveform signal processing module 542 includes a module 548 for adjusting morphology of the substitute waveform signal 541. Various embodiments of module 548 include a phase adjustment portion 549 to adjust the phase of the substitute waveform signal 541. Various embodiments of module 548 include a frequency adjustment portion
 25 550 to adjust the frequency or pitch of the substitute waveform signal 541. Various embodiments of module 548 include an amplitude portion 551 to adjust the amplitude or volume of the substitute waveform signal 541. Various embodiments of module 548 include a waveform length adjustment portion 552 to shorten the substitute waveform signal 541 by removing a front end portion and/or a back end
 30 portion of the substitute waveform signal 541. Various embodiments of module 548 include a smoothing filter portion 553 to smooth at least portions of the substitute

waveform signal 541. Various embodiments of module 548 include any one or more of the phase, frequency, amplitude, waveform length, and smoothing filter portions, or various combinations thereof. Thus, the waveform signal processing module 542 is capable of providing a calculated waveform based upon the sounds
5 immediately preceding the data transmission interference such that the resulting output acoustic signal from the receiver has the same pitch and volume and has its ends connected so that a user does not encounter a listening experience break during data transmissions and during transitions to and from data transmissions.

FIG. 6 illustrates a waveform signal processed by the waveform signal
10 processing module shown in FIG. 5, according to various embodiments of the present subject matter. The substitute waveform signal can be divided into a number of signal portions, with each portion including a number of bits. The waveform signal processing module 542 is capable of adjusting morphology parameters for any one, any combination or all of the signal portions. For example,
15 in order to connect the ends of the waveform signal to the preceding and succeeding acoustic signals, the waveform signal processing module 542 can smooth Signal Portion #1 and Signal Portion #N appropriately to provide a desired signal connectivity between a preceding acoustic-based signal, the substitute signal, and the succeeding acoustic-based signal.

20 One of ordinary skill in the art will understand that, the modules and other circuitry shown and described herein can be implemented using software, hardware, and combinations of software and hardware. As such, the terms module and switch are intended to encompass software implementations, hardware implementations, and software and hardware implementations.

25 One of ordinary skill in the art will understand, upon reading and comprehending this disclosure, that the present subject matter is capable of being incorporated in a variety of hearing instruments that use such near-field communication systems such as hearing aids, programmers, and assisted listening systems. For example, the present subject matter is capable of being used in hearing
30 aids such as in-the-ear, half-shell and in-the-canal styles of hearing aids, as well as for behind-the-ear hearing aids.

In various embodiments, the methods provided above are implemented as a computer data signal embodied in a carrier wave or propagated signal, that represents a sequence of instructions which, when executed by a processor cause the processor to perform the respective method. In various embodiments, methods
5 provided above are implemented as a set of instructions contained on a computer-accessible medium capable of directing a processor to perform the respective method. In various embodiments, the medium is a magnetic medium, an electronic medium, or an optical medium.

Although specific embodiments have been illustrated and described herein, it
10 will be appreciated by those of ordinary skill in the art that any arrangement which is calculated to achieve the same purpose may be substituted for the specific embodiment shown. This application is intended to cover adaptations or variations of the present subject matter. It is to be understood that the above description is intended to be illustrative, and not restrictive. Combinations of the above
15 embodiments, and other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the present subject matter should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.